Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 28(3): 1159 – 1184 (2024)
www.ejabf.journals.ekb.eg

Biotic and Abiotic Parameters in Five Selected Harbors in Egypt, South-Eastern Mediterranean Sea

Ahmed E. Alprol*, Ahmed M. M. Heneash, Samiha M. Gharib
National Institute of Oceanography and Fisheries (NIOF), Cairo 11516, Egypt
***Corresponding author:** ah831992@gmail.com

ARTICLE INFO

Article History:
Received: May 23, 2024
Accepted: June 14, 2024
Online: June 26, 2024

Keywords:
Climate change,
Mediterranean Sea,
Diversity index,
Species richness index,
Shannon index,
Phytoplankton,
Human activities

ABSTRACT

In this study, phytoplankton abundance, community structure, and physicochemical parameters were investigated for the most famous harbors in Egypt subjected to various anthropogenic wastes. The five studied harbors had > 5mg L^{-1} for dissolved oxygen and El-Dekhaila harbor was the most oxygenated (6.62mg L^{-1}). The higher significant values of nitrate, nitrite, and total phosphorus were observed in the Western Harbor. While, the highest significant BOD concentration was recorded at El-Dekhaila Harbor. Altogether, 117 species of phytoplankton were identified. Diatoms were the best-represented group, followed by dinoflagellates. Shannon Wiener's (H) diversity index of phytoplankton ranged from 0.203 to 2.872. Additionally, the species richness index (d) ranged between 1.046 and 1.996, and the evenness index (J) was between 0.295 and 0.761. Phytoplankton density showed a wide range between 27.33 × 10^3 cells L^{-1} in Damiatta Harbor and 3.06 × 10^6 cells L^{-1} in the Western Harbor. The composition and density of the dominant species in the two latter harbors differed compared to the results obtained 30 years ago, showing an increase in the density of winter phytoplankton compared to the formerly recorded data. In conclusion, environmental control assessment studies should be mandatory for upcoming projects at the harbors, with law enforcement, monitoring, and increased awareness being necessary for the coastal administration.

INTR ODUCTION

Releasing pollutants into the coastal environment is a primary human concern worldwide **(Poloczanska *et al*., 2013; Alprol., 2019)**. On the Egyptian Mediterranean coastline, which occupies the southeastern corner of the Mediterranean, there are numerous harbors used for international shipping. Harbors are subjected to multiple sources of pollutants and discharged wastewater, such as domestic and agricultural discharges and industrial waste as oil refiners that vary in severity from one harbor to another. These Harbors show high concentrations of phytoplankton densities due to the input of nutrients by the discharging waters, and these can be used as indicators of water quality **(Poloczanska *et al*., 2013)**. Therefore, studying the qualitative and quantitative properties of plankton has been essential in assessing the water quality of harbors **(Alprol *et al.*, 2021a; Zaki *et al.*, 2021; Alprol *et al.*, 2022)**. In recent years, a notable increase in harmful algae blooms has been recorded in the Western and El-Dekhaila Harbors. The blooms of the Euglenophyceae belonging to the genus *Eutreptiella* are documented in a new study by **Heneash *et al.* (2015)**. **Abdel Aziz and Aboul Ezz (2004)** addressed how garbage discharges affected zooplankton dynamics in the exact harbor. Water quality monitoring is crucial to locate the origins of contaminants entering water resources **(Alprol, 2019)**.

By analyzing patterns over time and comparing various water bodies, monitoring helps identify and address problems with water quality **(Chapman, 2021)**. The initial influence of pollutants is to degrade the physical quality of the water. Several studies have shown evidence that the effects of human activities, such as agricultural runoff, sewage, and industrial effluents, contaminate water resources **(Abualnaja *et al.*, 2021a; Abualnaja *et al*., 2021b; Alprol *et al.*, 2021b)**. In all aquatic habitats, phytoplankton is an essential organism in the food chain. Phytoplankton is a primary food source for zooplankton, invertebrates, and some fish species **(Metwally *et al.*, 2020)**. Therefore, studying phytoplankton is very important in monitoring water quality and pollution. The impact of human activity on water quality varies in intensity depending on where it occurs. The health of both people and ecosystems is significantly impacted by changes in physical, chemical, and biological features **(Heneash & Alprol, 2020)**.

The plankton and physicochemical conditions of El Dekhaila Harbor have been heavily investigated. **Zaghloul *et al.* (1995)** registered *Skeletonema costatum, Nitzschia microcephala, Protoperidinium minutum, Merismopedia punctata, Ankistrodesmus falcatus,* and *Euglena granulate* as the overwhelming species in El Dekhaila Harbor during 1990-1991. **Aziz *et al.* (2006)** gave a brief description of the relationship between phytoplankton and zooplankton. On the other hand, **Abdel-Aziz (2006)** presents an account of the vertical migration of zooplankton groups.

Ismael and Dorgham (2003) detected that the diatom flora during 1998- 1999 were dominated by *Cyclotella meneghiniana, C. striata, S. costatum, Prorocentrum micans, P. triestinum, Scrippsiella trochoidea, Gymnodinium minor,* the *Oscillatoria* sp., *Spirulina* sp., *Euglena acus,* and the *Chlorella* sp. The factors that controlled the composition and abundance of phytoplankton in El Dekhaila Harbor were also reported by **Khairy and Gharib (2017)**, who concluded that zooplankton grazing activity may be a significant influence in controlling the structure of the phytoplankton community in this harbor. **Shaltout and Abd-El-Khalek (2014)** studied the chemical properties of El Dekhaila Harbor water. **Abdel-Aziz and Ghobashi (2007)** reported that no attention was paid to studying the ecological and biological features of the other three harbors except for the first step in studying the dynamics of copepods in Damietta Harbor to establish a database on the Harbor's ecosystem. **Abdel-Halim and Aly-Eldeen (2016)** investigated the physicochemical parameters of the Sidi Kerir region in 2012. They calculated the water quality index (W.Q.I.), which demonstrated that the water of Sidi Kerir was between medium and good **(El-Sherbiny *et al*., 2006)**.

The novelty statement of this study is that there is no published work on the phytoplankton of Sidi Kerir, Port Said, and Damietta harbors. These harbors represent a prominent area for fishing, industrial development, goods transportation, trade operations, urban extension, and other tourism activities.

Accordingly, the current work aimed to investigate the structures, composition, and abundance of phytoplankton, in addition to the physicochemical parameters of five Egyptian Harbors (Sidi Kerir, El-Dekhaila, the Western, Damietta, and Port Said), providing a systematic list to increase the knowledge about the biological features of phytoplankton communities in these harbors, as well as addressing the concentration of nutrients related to the quality of the water in these five Egyptian harbors. This research would provide valuable information and observations that can be used to develop policies and regulatory frameworks for the sustainable management of these harbors.

MATERIALS AND METHODS

Study area

The study was conducted in the western part of Alexandria City between longitudes 29° 47′ and 29° 51′ E and latitudes 31° 7.5′ and 31° 9′ N, located El- Mex Bay. This bay occupies an area of 19.4km^2. In addition, it involves both the Western Harbor at the east and El Dekhaila Harbor at the west **(Zakaria *et al*., 2007)**. The Western Harbor has an area of 7.4km^2 and a depth range of 5.5— 16m **(Gharib & Dorgham, 2006)** and is connected to the sea through a small opening on its southwestern side. The harbor receives a massive amount of untreated wastewater. El-Dekhaila Harbor was constructed in 1986 with a water area of 2.74km^2 and a water depth of 4 to 20m **(Ismael & Dorgham, 2003)**. Far from the southwest of Alexandria by a 27km distance lies Sidi Kerir harbor, at latitude 31°4' 43" N and longitude 29°42' 31" E. The harbor is a small port with a limited use for the Sumid plant to serve oil tankers. The harbor water is directly affected by the power station and petroleum pipeline companies **(El-Sadaawy *et al*., 2022)**. Damietta Harbor (31°27'57.2" N 31°45'54.2" E) was constructed in 1987, with a water area of 3.3km^2 and a maximum depth of 15m, located 8km west of the entrance to the Damietta branch of the Nile River, 250km east of Alexandria. The port is connected to the Damietta branch of the Nile River through a narrow canal used to transport imported and exported goods **(El-Ghobashi e*t al*., 2006)**. East of Alexandria at about 226 and 70km east of Damietta City, Port Said Harbor (31°14'01.7" N 32°19'33.3" E) is located. It was built in 2000 at the northern entrance to the Suez Canal and is considered an essential Egyptian port in the Mediterranean Sea. The harbor has a water area of 1.7km^2 **(Soliman, 2006)**. The actual water area of the studied harbors was taken from (M.G.S. Egypt Moukhtar Group of Shipping) http://www.mgs-egypt.com/porfolio.html. Fig. (1) shows the location of the sampling stations for the Harbors reviewed.

Methods

Sampling design

The survey was carried out during the second half of February 2018 using a small research vessel. At each station, water samples were collected by a Niskin bottle at the surface (50cm) for physicochemical parameters. Water samples were collected parallel to plankton collection in the surface water layer using standard methods APHA **(APHA, 1998)**.

Water quality measurements

A portable digital P.H. meter (HANAA instrument) was used to measure the pH value in the field, a Beckman salinometer (Model NO.R.S.10) was used to monitor the water's salinity, and the thermometer measured the temperature of the water (HANAA instrument-Model NO.R.S.10). Dissolved oxygen (DO, mg L^{-1}), nitrate (NO_2, µg L^{-1}), nitrite (NO_3, µg L^{-1}), ammonia (NH_4, µg L^{-1}), total nitrogen (T.N., µg L^{-1}), total phosphorus (TPO_4, µg L^{-1}), chemical oxygen demand (COD, µg L^{-1}), and biological oxygen demand (BOD, µg L^{-1}) were measured according to the standard methods described in **APHA (1998)**.

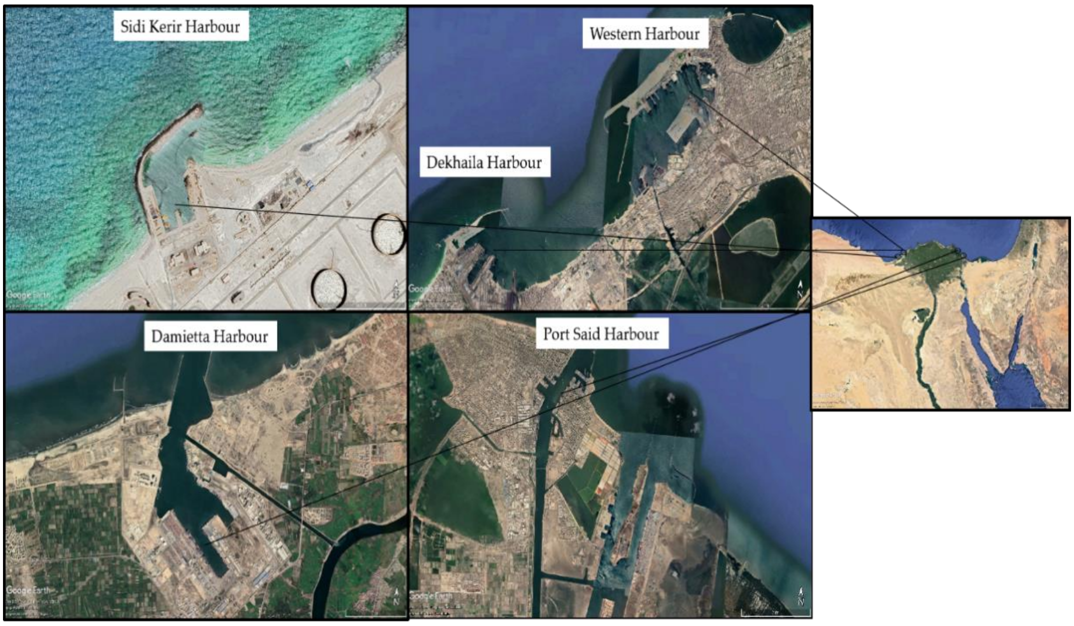

Fig. 1. Map of the Egyptian studied harbors; the location of sampling stations for each harbor is reported using labels and black spots

Phytplankton analysis

Water samples for phytoplankton were collected by a Niskin bottle at the surface (50cm) and subsurface layers (mean depth 10m). Immediately after sample collection, 5ml of 4% formalin was added to preserve the samples. The preserved samples were held for 24 hours to allow water-suspended plankton to settle. After 24 hours, the supernatant was carefully eliminated without disturbing the sediments, and the concentrated sample's ultimate volume was around 50mL. The total number of samples was equal to 46 samples: 20 samples (10 surface and 10 subsurface layers) for each of Damietta and Port Said Harbors; nine samples (5 surface and 4 subsurface layers) for Sidi Kerir Harbor; twelve samples (6 for each surface and subsurface layers) for the Western Harbor; and five samples (3 surfaces and 2 subsurface layers) for El-Dekhaila Harbor. As previously described **(Zaki *et al*., 2021)**, Utermöhl's method was used to verify, identify, and count the phytoplankton samples using 2-mL settling chambers and a Nikon TS 100 inverted microscope at 400 magnifications **(Edler & Elbrächter, 2010)**. Algal cells were identified to the lowest taxonomic level possible and expressed as cells L^{-1}. Http://www.marbef.org/data/index.php. The World Register of Marine Species checked each species. To express the percentage of phytoplankton, the concentration of phytoplankton cells was divided by the total concentration of all particles in the water sample (including phytoplankton, zooplankton, detritus, etc.), and then multiplied by 100.

Statistical analyses

Statistical analysis of water quality parameters (mean ± S.D.) was calculated using the IBM SPSS Statistics software (I.B.M., v.23) using the one-way analysis of variance (ANOVA), followed by Duncan's post-hoc test at a significant P-value ≤ 0.05. Four indices were used to estimate species diversity: Shannon and Wiener (H') **(Shannon & Wiener,**

1963), species evenness (J') **(DeJong, 1975)**, species richness index (d') **(Wu, 1982)**, and Boyd's diversity index **(Wolda, 1983)**. The Shannon-Wiener diversity index is based on species number and their relative concentration in each sample. In contrast, the Boyed index is based on general numbers and calculated using a mathematical formula. Pearson's correlation coefficient (r) was utilized for the simple relationship analyses with the variables (N = 46) with the SPSS 17.0 Statistical Package Program. Principal component analysis (P.C.A.) and cluster analysis were shown to compare physico-chemical factors, heavy metals and stations. It was realized by I.B.M. SPSS Statistics program, Version 22.

RESULTS

Physicochemical parameters

Table (1) shows the values (Mean ± S.D.) of water physicochemical parameters of the different five studied harbors. No significant (*P*< 0.05) differences were detected in pH, salinity, NH_4, and T.N. The highest non-significant (*P*< 0.05) pH value was observed in Damietta Harbor, and the lowest was recorded in Western Harbor. The salinity values ranged between 34.63ppt in Western Harbor and 38.37ppt in Sidi Kerir Harbor. The five studied harbors recorded values > 5mg L^{-1} for the dissolved oxygen (DO), and El-Dekhaila Harbor was the most oxygenated (6.62 mg L^{-1}). The higher non-significant NH_4 values were observed in the Western, El-Dekhaila, and Port Said harbors, while the lowest NH_4 value was recorded in Sidi Kerir Harbor. The higher non-significant TN value was observed in the Western Harbor, while the lowest TN value was recorded in the Sidi Kerir Harbor. The higher significant value of NO_2, NO_3, and TPO_4 was observed in the Western Harbor. In comparison, the lower values of NO_2 and NO_3 were observed in Damietta, and the lower value of TPO_4 was observed in Sidi Kerir Harbor. The minimum significance COD concentration was recorded at Sidi Kerir Harbor and the Western Harbor, while the maximum significant value was detected at El-Dekhaila and Port Said harbors. The highest significant BOD concentration was recorded at El-Dekhaila Harbor, while the lowest was reported at the habour of Damietta (Table 1).

Table 1. Water physicochemical parameters of experimented harbors at the surface layer

Physicochemical parameter*	**Harbors**				
	Sidi Kerir	**Western**	**El-Dekhaila**	**Damietta**	**Port Said**
PH	7.89±0.15	7.61±0.69	8.09±0.16	8.43±0.78	8.33±0.64
Salinity (ppt)	38.37±2.60	34.63±1.92	37.15±2.60	36.47±3.32	36.13±2.84
DO (mg L^{-1})	6.08±0.93	5.68±0.78	6.62±0.29	6.34±0.78	5.67±0.64
NH_4 (µg L^{-1})	3.47±1.50	14.79±4.33	14.64±3.00	9.35±2.88	14.68±3.21
TN (µg L^{-1})	9.33±3.13	15.21±3.46	13.38±2.18	10.09±2.06	14.31±0.81
NO_2 (µg L^{-1})	3.48±0.70^{bc}	7.68±0.79^{a}	5.57±0.50^{ab}	2.62±0.23^{c}	7.35±0.61^{a}
NO_3 (µg L^{-1})	39.03±8.26^{ab}	57.63±4.94^{a}	54.47±3.76^{a}	21.48±5.16^{b}	43.33±4.50^{ab}
TPO_4 (µg L^{-1})	1.64±0.71^{ab}	4.58±0.64^{a}	3.69±0.62^{ab}	4.56±0.56^{a}	1.50±0.68^{b}
COD (µg L^{-1})	3.65±0.47^{c}	4.26±0.55^{c}	27.82±4.32^{a}	9.79±1.53^{b}	26.26±3.84^{a}
BOD (µg L^{-1})	3.53±0.49^{ab}	5.55±0.62^{ab}	13.46±3.41^{a}	1.98±0.33^{b}	11.08±3.59^{ab}

* The presented data are Means ± SD (n = 3). Different letters in the same column are significantly different (*P*< 0.05). The absence of letters in the same row means no significant differences. DO: Dissolved oxygen, NO_2: nitrate, NO_3: nitrite, NH_4: ammonia, TN: total nitrogen, TPO_4: total phosphorus, COD: chemical oxygen demand, and BOD: biological oxygen demand.

Phytoplankton community and diversity

The phytoplankton assemblage of the five harbors was composed of 117 taxa through the analysis of 51 samples collected at two depths during winter 2020 (Table 2), and every species was checked up by http://www.marbef.org/data/index.php and World Register of Marine Species (Table 2). In general, the diatoms exhibited the greatest diversity of 68 species with 35 genera, while the dinoflagellates showed 21 species of 10 genera. *Chlorophyceae*, *Cyanophyceae*, and *Euglenophyceae* were represented by 16, 7, and 4 species, belonging to 9, 6, and 2 genera, respectively. While for the lowest diversity, one species was observed with *Dictyochophyceae* (Table 2). 40 species of this community were rare, having a frequency of persistence of about 3% in all samples, but they were critical since they are valuable to species diversity. *Bacillariophyceae* and the dinoflagellates out numbered all other taxonomic groups qualitatively (76.07%) and quantitatively (96.65%).

They stood out as the two most diverse groups, accounting for 58.12 and 17.95% of all species. Eleven recorded species were restricted to Damietta Harbor, while nine were restricted to Sidi Kerir and Port Said harbors. On the other hand, 6 and 5 were observed only in El-Dekhaila and the Western harbors, respectively. The structure of the phytoplankton community of Damietta and Port Said harbors was highly diverse, with 68 and 66 species identified, respectively. The Sidi Kerir and the Western harbors have approximately similar numbers of species (52 and 51 species), while a conspicuously smaller number (43 species) was found in El-Dekhaila Harbor (Table 2).

Table 2. Diversity and abundance of the phytoplankton species at the different investigated harbors

Species	Harbors				
	Sidi Kerir	**El-Dekhaila**	**Western**	**Damietta**	**Port Said**
Bacillariophyceae	38	22	27	37	39
Dinoflagellates	9	7	12	15	16
Chlorophyceae	4	9	8	10	8
Cyanophyceae	0	3	3	2	0
Euglenophyceae	1	2	1	4	2
Dictyochophyceae	0	0	0	0	1
Number of species	52	43	51	68	66
diversity index (H`)	0.806	1.294	1.211	1.217	1.08
Evenness index (J)	0.559	0.729	0.671	0.6753	0.588
Richness index (R)	0.759	1.063	1.017	0.948	0.954
Total abundance (Ind. m^3)	1054815	363631	3446671	93791	301403

Twelve species occurred at all sampling stations of the five harbors (5 diatoms, 4 dinoflagellates, 2 green algae, and one euglenoid): *Asterionellopsis glacialis* (Castracane) Round, 1990, *Pantocsekiella kuetzingiana* (Thwaites, 1848) K.T. Kiss and Ács, 2016, *Navicula gracilis Lauby*, 1910, *Pseudo-nitzschia delicatissima* (Cleve) Heiden, 1928, *Skeletonema cf costatum* (Greville) Cleve, 1873, *Prorocentrum lima* (Ehrenberg) F. Stein, 1878, *Prorocentrum triestinum* J. Schiller, 1918, *Protoperidinium cerasus* (Paulsen) Balech, *Scrippsiella trochoidea* (Stein) Loeblich III, 1976, *Chlorella marina Butcher*, 1952, *Scenedesmus quadricauda* (Turpin) Brébisson in Brébisson and Godey 1835 and the *Eutreptiella* sp.

The highest diversity (H′) and evenness (J) indices of phytoplankton, 2.872 and 0.899, respectively, were recorded at Port Said Harbor, while the lowest were 0.203 and 0.075 at the Western Harbor. Boyed index ranged between 0.56 and 1.76. On the other hand, diversity, evenness, and richness showed the same trend in the studied harbors. The correlations between phytoplankton counts and species diversity indices were: r = -0.567, $P< 0.001$ for Shannon index; r =-0.353, $P< 0.05$ for Boyd diversity index; r=-0.616, $P< 0.001$ for evenness index and r=-0.340, $P< 0.05$ for Margalef index. If the values of Shannon or Boyed diversity indices obtained are more than 4, it indicates clean water; values between 3 and 2 indicate moderate pollution, while values less than 1 indicate heavily polluted water. From the resultant values of Shannon diversity, the Western Harbor is heavily polluted and the other four harbors are moderately polluted. The diversity index of Boyd indicates that Damiatta and Port Said Harbors are moderately polluted, while Sidi Kerir, El-Dekhaila, and the Western harbors sometimes tend to become heavily polluted. The dominant species differed in each harbor and may also differ in the two depths of the exact harbor (Table 3).

The lowest phytoplankton density was observed in Damiatta Harbor with means of 2.7 3 $\times 10^4 \pm 0.85 \times 10^4$ cells L^{-1} for the surface water and $6.65 \times 10^4 \pm 11.47 \times 10^4$ cells L^{-1} at the subsurface layer. Generally, density was higher in the subsurface layer. Phytoplankton cell density varied from 1.82×10^4 (station 2) to 3.77×10^4 cells L^{-1} (station 5) in the surface layer and between 1.51×10^4 (station 1) and 27.11×10^4 cells L^{-1} (station 5) in the subsurface layer. The highest numbers of species were recorded at stations 5 and 1 (26 and 25). The diatoms were most frequently observed at all stations (22.74- 100%), except stations 2 and 4, where members of the Chlorococcales (41.22%) and dinoflagellates (68.17%) were the dominant groups. *Chaetoceros curvisetus* and *Arerataulina pelagica* were the dominant diatom species, and *Protoperidinium minutum* from the dinoflagellates. *Crucigenia tetrapedia* was predominant at station 1 and co-dominant with *Scenedesmus quadricauda* at station 5. Phytoplankton abundance showed vertical stability of the water column in Sidi Kerir Harbor with means of $53.43 \times 10^4 \pm 25.00 \times 10^4$ cells L^{-1} in the surface layer and 52.05 $\times 10^4 \pm 35.10 \times 10^4$ cells L^{-1} in the subsurface layer. The total phytoplankton abundance in the surface water varied between 28.20×10^4 cells L^{-1} (station 1) and 87.82×10^4 (station 4), while the subsurface layer recorded values of 12.71×10^4 (station 1) and 97.74×10^4 cells L^{-1} (station 2). Diatoms dominated the phytoplankton at all the sampling stations, representing > 93% at the two layers. Phytoplankton abundance was characterized by a peak corresponding to the diatom blooms dominated by *Skeletonema cf costatum* in the bottom (62.56% of the total abundance) and *Asterionellopsis glacialis* in the surface water (48.68% of the total), as presented in Table (3).

Spatial fluctuation in Port Said Harbor varied widely in abundance and the presence of dominant species. Bacillariophyceae was the dominant division at all stations (> 85%). *Chaetoceros affinis*, *Chaetoceros curvisetus* and *Asterionellopsis glacialis* were the dominant species in the surface water, while *Asterionellopsis glacialis*, *Chaetoceros didymus*, and *Cerataulina pelagica* were those recorded in the subsurface layer. Generally, density was higher in the subsurface layer (19.3×10^4 cells L^{-1}) than in the surface layer (10.9×10^4 cells

L^{-1}). Phytoplankton cell density varied from 7.38 × 10^4 (station 4) to 18.39 × 10^4 cells L^{-1} (station 3) in the surface layer and between 4.87 × 10^4 (station 5) and 56.67 × 10^4 cells L^{-1} (station 2) in the subsurface layer. Among the dinoflagellates observed in the Port Said Harbor, *Scrippsiella trochoidea, Prorocentrum micans, Protoperidinium minutum,* and *Protoperidinium conicum* were the major ones.

Spatial fluctuation in El-Dekhaila Harbor was different in abundance and dominant species. For the surface layer (23.91 × 10^4 cells L^{-1}), *Prorocentrum triestinum* was dominant at stations 1 and 2, while *Skeletonema cf costatum* and *Thalassiosira decipiens* were dominant at station 3. On the other hand, the subsurface layer (mean 12.46 x 10^4 cells L^{-1}) was dominated by *Thalassiosira decipiens, Skeletonema cf costatum,* and *Prorocentrum triestinum*. The Western Harbor harbored recorded a high density of phytoplankton with a mean of 306.10 × 10^4 ± 394.98 × 10^4 cells L^{-1} at the surface water and 38.57 × 10^4 cells L^{-1} ± 31.64 x 10^4 cells L^{-1} at the subsurface layer. The total abundance in the surface layer varied between 60.07 × 10^4 cells L^{-1} (station 6) and 1098.59 × 10^4 cells L^{-1} (station 1) and between 6.83 × 10^4 (station 5) and 97.11 × 10^4 (station 1) at the subsurface layer. The dominant group was the dinoflagellates at all stations, except for station 5 of the bottom layer, where diatoms were predominant. *Prorocentrum triestinum* formed a massive bloom, but this bloom was restricted to the surface water of station 1, whereas *Asterionellopsis glacialis* formed the main component in the bottom layer of station 5. Euglenophyceae was well developed, reaching 22.57 × 10^4 cells L^{-1} at station 1 of the surface water. The phytoplankton abundance and community structure showed a non-mixed vertical profile concerning phytoplankton cells. Diversity was greatly affected by the *Prorocentrum triestinum* bloom.

Table 3. Top 10 main species of phytoplankton and their percentage of the whole phytoplankton of the Egyptian Harbors

Western Harbor	%	El-Dekhaila Harbor	%	Damietta Harbor	%	Port Said Harbor	%	Sidi Kerir Harbor	%
Surface layer									
Prorocentrum triestinum	89.6	*Prorocentrum triestinum*	50.57	*Chaetoceros curvisetus*	14.03	*Chaetoceros affinis*	19.32	*Skeletonema costatum*	62.56
Exuviaella marina	3.92	*Thalassiosira decipiens*	8.12	*Cerataulina pelagica*	11.12	*Chaetoceros curvisetus*	13.48	*Asterionellopsis glacialis*	14.39
***Eutreptiella* sp.**	2.43	*Thalassiosira rotula*	7.53	*Chaetoceros affinis*	7.43	*Asterionellopsis glacialis*	13.27	*Pseudo-nitzschia delicatissima*	4.45
Asterionellopsis glacialis	0.69	*Skeletonema costatum*	6.87	*Asterionellopsis glacialis*	6.32	*Cerataulina pelagica*	10.6	*Prorocentrum triestinum*	3.65
Cerataulina pelagica	0.64	*Cyclotella kuetzingiana*	6.45	*Bacteriastrum hyalinum*	6.32	*Chaetoceros didymus*	4.73	*Leptocylindrus minimus*	3.45
Thalassiosira decipiens	0.5	*Cerataulina pelagica*	4.22	*Thalassiothrix frauenfeldii*	6.26	*Skeletonema costatum*	4.68	*Thalassiothrix longissima*	2.77
Skeletonema costatum	0.47	*Scenedesmus quadricauda*	3.77	*Prorocentrum micans*	5.2	*Thalassiothrix frauenfeldii*	3.74	*Chaetoceros affinis*	1.69
Alexandrium minutum	0.24	*Asterionellopsis glacialis*	2.35	*Crucigenia tetrapedia*	5.06	*Scrippsiella trochoidea*	3.1	*Chaetoceros decipiens*	1.48
Cyclotella kuetzingiana	0.22	*Leptocylindrus minimus*	2.15	*Hemiaulus hauckii*	4.52	*Cyclotella kuetzingiana*	2.2	*Coelastrum microporum*	0.89
Pseudo-nitzschia delicatissima	0.21	*Exuviaella marina*	2	*Chaetoceros borealis*	2.96	*Pseudo-nitzschia delicatissima*	2.13	*Prorocentrum micans*	0.48

Subsurface layer

Western Harbor	**%**	**El-Dekhaila Harbor**	**%**	**Damietta Harbor**	**%**	**Port Said Harbor**	**%**	**Sidi Kerir Harbor**	**%**
Prorocentrum triestinum	63.44	*Prorocentrum triestinum*	42.78	*Asterionellopsis glacialis*	48.68	*Asterionellopsis glacialis*	21.57	*Skeletonema costatum*	54.31
Cerataulina pelagica	63.6	*Thalassiosira decipiens*	18.49	*Skeletonema costatum*	10.55	*Chaetoceros didymus*	18.5	*Asterionellopsis glacialis*	26.31
***Eutreptiella* sp.**	6.26	*Skeletonema costatum*	11.37	*Cerataulina pelagica*	8.74	*Cerataulina pelagica*	13.88	*Prorocentrum triestinum*	4.76
Exuviaella marina	3.11	*Cyclotella kuetzingiana*	6.89	*Chaetoceros affinis*	8.19	*Chaetoceros affinis*	13.09	*Pseudo-nitzschia delicatissima*	4.55
Thalassiosira decipiens	3.1	*Crucigenia tetrapedia*	3.55	*Chaetoceros didymus*	4.9	*Chaetoceros curvisetus*	6.01	*Thalassiothrix longissima*	1.45
Biddulphia alternans	2.58	*Scenedesmus quadricauda*	3.55	*Leptocylindrus danicus*	3.51	*Bacteriastrum hyalinum*	3.05	*Leptocylindrus minimus*	0.88
Leptocylindrus danicus	2.43	*Eutreptiella* sp.	2.58	*Thalassiothrix frauenfeldii*	2.43	*Skeletonema costatum*	2.55	*Chaetoceros affinis*	0.81
Protoperidinium minutum	1.31	*Diploneis* sp.	1.78	*Streptotheca thamensis*	2.05	*Chaetoceros borealis*	2.39	*Thalassionema nitzschioides*	0.78
Gyrodinium spirale	1.16	*Exuviaella marina*	1.73	*Chaetoceros curvisetus*	1.56	*Rhizosolenia calcar avis*	1.88	*Grammatophora angulosa*	0.72

Spatial similarity with cluster analysis and principal

Component analysis (PCA)

Cluster analysis was applied to find out the similarity groups between the parameters and different stations. It produced a dendrogram (Fig. 2), which reports all eleven parameters in three clusters. The first cluster includes Sidi Kerir Harbor, which is relatively similar to Damietta Harbor and the other stations, which have an average of 59.8%. The second cluster includes both the Western Harbor and El-Dekhaila Harbor. The third cluster includes Port Said Harbor and the second cluster with an average of 40.3%. The correlation between different parameters was profiled using P.C.A. Table (4) and Fig. (3) show the correlation where all parameters are represented concerning the first (P.C.A.1) and the second (P.C.A.2) principal components. Based on the P.C.A. analysis, in a decreasing order, diversity index, richness index, B.O.D., and NH_4 were highly and positively correlated to PCA1, whereas DO, salinity and pH parameters were negatively correlated. Compared with axis P.C.A.2, nitrate and total nitrogen were negatively correlated in a decreasing order, whereas the other parameters were negatively correlated.

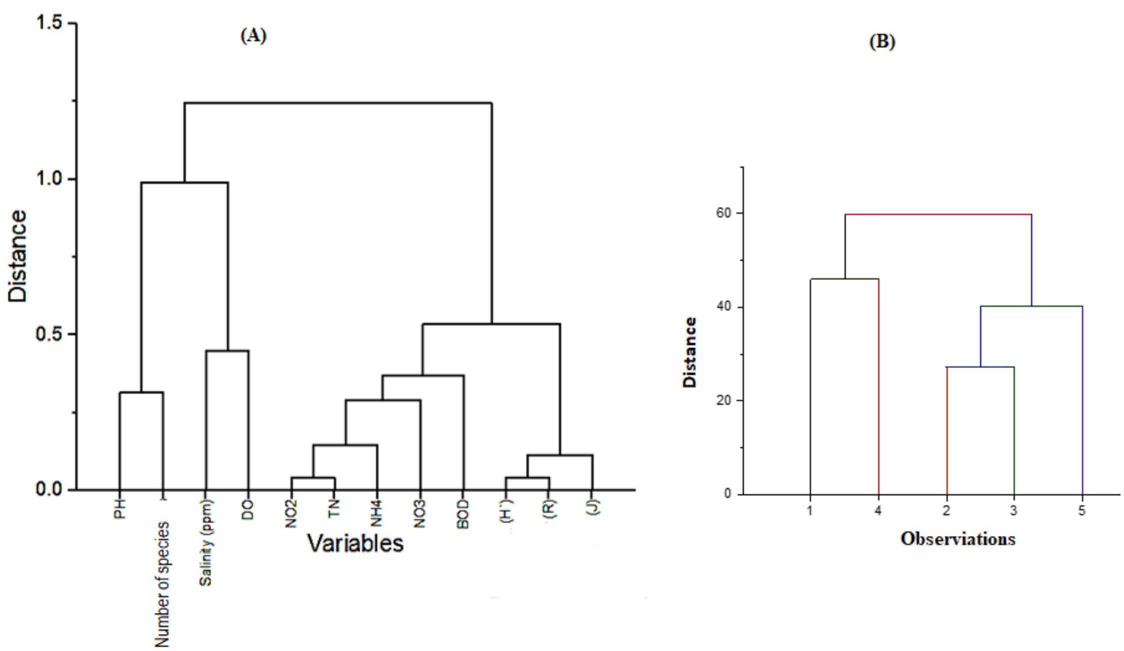

Fig. 2. Tree diagram for **(A)** different parameters and **(B)** five stations

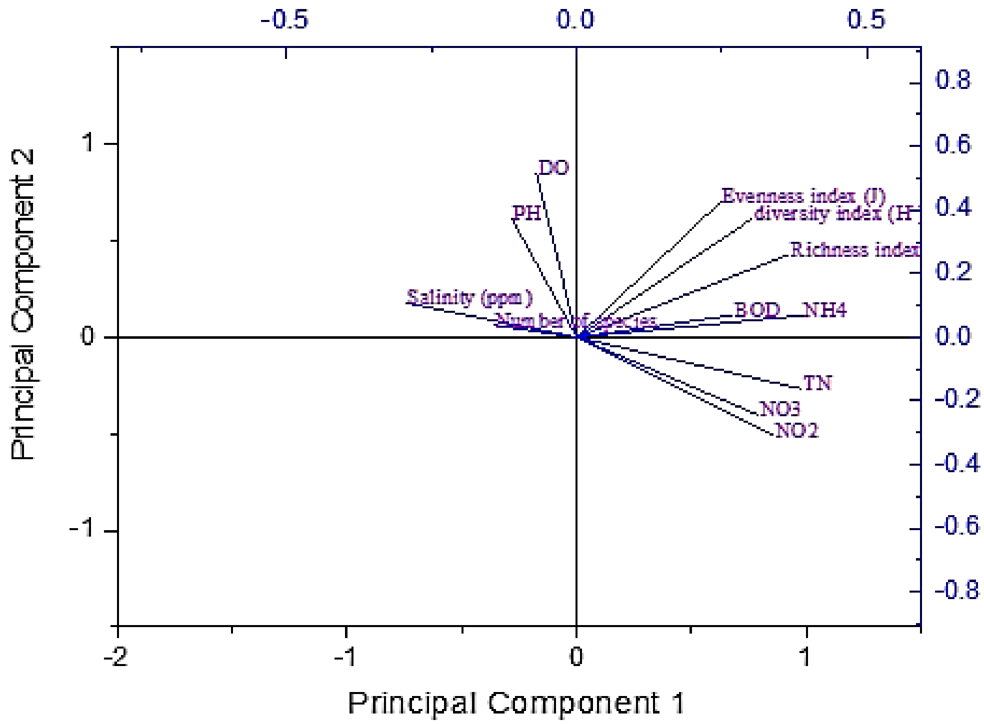

Fig. 3. Distribution of the parameters regarding the first and the second principal components

Table 4. Correlation between variables as shown by principal component analysis (P.C.A.).

Parameter	Coefficient of PC1	Coefficient of PC2
PH	-0.11	0.38
Salinity (ppm)	-0.29	0.11
DO	-0.07	0.52
NO_2	0.34	-0.31
NO_3	0.31	-0.24
NH_4	0.39	0.07
TN	0.39	-0.16
BOD	0.27	0.07
Number of species	-0.14	0.04
diversity index (H`)	0.30	0.37
Evenness index (J)	0.25	0.43
Richness index (R)	0.37	0.26

DISCUSSION

Physicochemical parameters

Harbors are semi-closed basins, mainly affected by anthropogenic inputs of nutrients and pollution **(Alprol *et al.*, 2023)**. Moreover, they are considered to be highly dynamic environments causing highly harmful effects on the microorganisms **(Davidson *et al*., 2014)**. Countless microorganisms can be adaptive to changes in the environment. Still, in many cases, they fail to tolerate profound ecological changes and turn into very harmful organisms viz. phytoplankton. Phytoplankton is an essential tool for identifying the state of the water ecosystem because of its sensitivity to any change in the hydrological conditions. The results of the present study showed that the water quality condition was measured using various physical and chemical methods **(Zein *et al*., 2014)**.

Furthermore, monitoring the phytoplankton community is crucial because monitoring based solely on physicochemical analysis is occasionally insufficient. In the five harbors, the pH level was discovered to be somewhat essential. The U.E.U. (European Union) sets pH limits for aquatic life and fisheries at 6 to 10 **(Nguyen *et al*., 2018)**.

Also, the wide diversity of aquatic animals' favor of pH fluctuated between 6.50 and 8.00. Out of this range, the variety could decrease as it stresses the physiological methods of the greatest organisms and can decrease reproduction. In addition, the pH value is greatly influenced by the photosynthetic action of algal biomass and the quantity of sewage discharged effluents into the hot spot areas **(Khedr *et al*., 2019)**. Additionally, low pH can make toxic elements more available for uptake by aquatic organisms. Latitude, depth, and the percolation method all affect the salinity of natural water. Salinity fell within the observed range of 34– 38ppm. In addition to the dissolved oxygen in the water, it is essential for respiration; therefore, marine life must be present. Wave action and diffusion dissolve a significant amount of oxygen in the water. These results are according to the acceptable limits (4.0 - 5.0mg L^{-1}) **(El-Feky *et al.*, 2019)**. An oxygen deficit occurs in most harbors due to heavy contamination caused by the organic material decomposition. This study noted that low concentrations of dissolved oxygen, pH, and salinity were recorded in the Western Harbor, indicating this area's high pollution. **El-Amier *et al*. (2018)** mentioned that as the degree of pollution rises, the concentrations of three factors: dissolved oxygen, pH, and salinity decrease.

Ammonia is a reliable indicator of the level of water pollution. It is a highly changeable parameter that the bacterial breakdown of organic materials swiftly produces and ammonification processes **(Alprol *et al.*, 2021a)**. Nitrite is an intermediate compound that can be eliminated from an aqueous solution through nitrogen assimilation via phytoplankton. The nitrite concentration reached a minimum in most zones of the harbors under study. The maximum mean may be attributed to anticlockwise water circulations that bring large amounts of pollutants and the secretion of extracellular nitrite via phytoplankton.

Nonetheless, nitrate is the end product of the nitrification method, which is the most stable shape of inorganic nitrogen products in oxygenated water **(Heneash & Alprol, 2020)**. Low bioavailable nutrient salts and vice versa accompany areas suffering from high photosynthetic activities. The lowest nitrate values could be due to absorption through plants and the denitrification method.

Total PO_4 is used as an indicator of excess pollution in domestic effluents, sewage, and agricultural areas. In the present study, the concentrations of phosphate and NH_4-N are lower than those recorded on the El-Gameel coast in Port Said, Egypt by **Gaballah and Touliaba, (2014)**. The decrease in phosphorous may be due to its adsorption on hydrous Al_2O_3 and Fe_2O_3; its assimilation through algae, bacteria, or aquatic weeds may correlate to its little seawater residence period **(El Zokm *et al.*, 2018)**. Moreover, total nitrogen is vital in eutrophic waters, specifically for those contaminated by animal wastes, domestic sewage, and fertilizer runoff. The variation in nitrogen was inversely related to the variation in dissolved oxygen, possibly due to the high bacterial activity correlated with the high nitrogen content due to the drainage water, which comprises high amounts of nutrients **(El-Zeiny & El-Kafrawy, 2017)**. The total amount of oxygen needed to oxidize all the organic matter and oxidizable substances in the water sample into CO_2 and H_2O is known as the chemical oxygen demand **(Federation & Association, 2005)**. Organic matter is mainly created by the photosynthesis of phytoplankton in the extremely eutrophied water body. The COD indicates an organic pollution caused by industrial activities **(Heneash *et al.*, 2021)**. In addition, BOD represents the quantity of oxygen requisite by living aquatic organisms for their physiological method. The average BOD concentration was recorded at 7.18mg L^{-1}. Data collected at the end of the study period showed that the COD values were greater than the BOD values. The increased effluents of various contaminants may be to blame for the elevated BOD and COD levels in the study sites. The current data generally differ from what **Faragallah *et al*. (2009)** reported for Damietta Harbor, Egypt, which exposed the lowest amounts of COD and BOD in the research area.

Phytoplankton community and diversity

The current study analyzed the composition of the phytoplankton species in five Egyptian Harbors in the southeastern Mediterranean Sea during the winter season of 2020. Many studies were conducted on the phytoplankton of the Western Harbor; however, less attention has been paid to El-Dekhaila Harbor, while the study presents the first compilation of phytoplankton structure in Port Said, Damiatta and Sidi Kerir harbors.

Due to the high dynamics of the Western and El-Dekhaila harbor's water, changes in the phytoplankton community structure, species composition, and phytoplankton peaks occurred. Discharged waters and invasive species by ballast water may be responsible for changing the dominant species from one year to another. They may also be responsible for the complete disappearance of the dominant species in the next year. The average phytoplankton density in the Western Harbor was 3.06 x10^6 cells L^{-1}, in which the dinoflagellates *Prorocentrum triestinum* constituted > 95% of the total phytoplankton counts. The most recent study carried out during 2012 - 2013 by **Heneash *et al.* (2015a)** showed that the phytoplankton means during winter 2012 was $5.74 \pm 5.20 \times 10^4$ cells L^{-1}, in which diatoms described 92% of cell abundance, and the highest taxa were: *Skeletonema cf. costatum* and *Asterionellopsis glacialis* during spring 2012 *Eutreptiella* fitting to class Euglenophyceae overwhelming and arriving a mean of 17×10^6 cells L^{-1}.

In the same study, the phytoplankton mean during winter 2013 was 29.2± 18.8 10^4 cells L^{-1}, and the results revealed that diatoms deceased. Dinoflagellates increased, and the dominant diatom species was *Skeletonema costatum*; the most frequent dinoflagellates were *Prorocentrum triestinum*. Additionally, **Heneash *et al.* (2015)** emphasized that not only is discharged wastewater hazardous, but also ballast water may have deleterious consequences to biosystems and introduce alien organisms that are toxic and non-toxic.

An earlier study in the same harbor during 1999 – 2000, **Aziz *et al*. (2006)** showed that dinoflagellates contributed 57% of the total phytoplankton density. The dominant species were *Prorocentrum triestinum*, *Alexandrium minutum*, and *Skeletonema* cf. *costatum*. Another study conducted in 1989 by **Zaghloul *et al*. (1995)** showed the main species were *Pseudonitzschia delicatissima*, *Prorocentrum cordatum*, *Cyclotella meneghiniana*, and *P. micans*. **Halim (1960)** detected *Alexandrium minutum* for the first time in Egyptian Harbors, forming a red water discoloration. Additionally, it has been commonly reported from the Mediterranean Sea **(Koray, 2002)**. This species became the most predominant species in Alexandria's Harbor and neritic waters for many years, reaching a maximum of 24 x10^6 cells L^{-1}, as reported by **Labib and Halim (1995)**. The number of species has decreased significantly in the present study and has never dominated the phytoplankton of the Mediterranean lagoons **(Giacobbe *et al.*, 1996)**.

Phytoplankton density in El-Dekhaila Harbor showed a pronounced decrease to reach a mean of 23.91×10^4 cells L^{-1} with the dominance of *Prorocentrum triestinum* and, to a lesser extent *Skeletonema* cf *costatum* and *Thalassiosira decipiens*. The study conducted in 2012 by **Khairy and Gharib (2017)** showed that diatoms constituted 84.58% of the total phytoplankton density in which the Prorocentrum spp., *Skeletonema* cf. *costatum*, *Chaetoceros curvisetus*, and *Pseudo-nitzschiaseriata* were often recorded. The critical question is why the Western Harbor always has dense blooms of dinoflagellates, regardless of their taxa that differ from the other harbors. The first possibility is that this harbor is Egypt's oldest and largest harbor. This observation corroborates the results of **Vila and Masó (2005)**. The second is that the living dinoflagellates already present in the phytoplankton community can produce resting cysts when subjected to extreme environmental conditions **(DALE, 1983)**. These cysts accumulate in the water sediments and may remain for many years. They can be considered to be a biological indicator of the time and degree of environmental changes.

The organic nature of the cyst walls makes them resistant to degradation **(Fischer *et al*., 2018)** and under favorable germination conditions (temperature, light, and nutrients), the cysts change to vegetative cells. They may be an essential factor in the onset of dense blooms in the ecosystems. Studying the occurrence of dinoflagellate cysts in the sediments can predict blooms. Unfortunately, little research was done on the information on the dinoflagellate cysts of the Egyptian Mediterranean sediment **(Fatourou *et al*., 2023)**.

Dinoflagellate cysts are microscopic structures made by the single-celled aquatic organisms known as the dinoflagellates. These structures can be used as important historical environmental indicators. Dinoflagellate cysts are abundant and present in the sedimentary strata of the Egyptian Mediterranean, as reported by **Kholeif *et al*. (2020)**. The study provides insight on historical environmental changes, such as fluctuations in salinity, productivity, and sea surface temperature, by examining these cysts.

Harmful algal bloom cases are serious problems that occur in the coastal areas of the Mediterranean Sea, especially harbors, and have been a problem in the Egyptian harbors all over the years **(Tsikoti & Genitsaris, 2021)**. Dinoflagellates (*Prorocentrum minimum*, *Prorocentrum micans*, and *Alexandrium tamarense*) and diatoms (*Pseudo-nitzschia* species, for example) were the most common detrimental species, and potentially poisonous taxa were found in three major Egyptian harbors (Damietta, Alexandria, and Port Said) **(Tsikoti & Genitsaris, 2021)**.

Prorocentrum Ehrenberg is a genus in tropical marine waters **(Pei *et al.*, 2022)**. It includes > 50 marine species **(Tarazona-Janampa *et al*., 2020)**. Most of them are planktonic and benthic and secrete toxins. *Prorocentrum triestinum* is one of the most taxa flourishing along the Mediterranean coast. It is a cosmopolitan species in neritic and oceanic waters **(Ndhlovu *et al.*, 2017)**. However, research on population dynamics and bloom production clarifies the variables influencing *P. triestinum* populations' expansion and growth in the Mediterranean Sea. Through the identification of favorable environmental conditions for bloom formation, this research advances our knowledge of the dynamics of harmful algal blooms and offers crucial information for the creation of mitigation strategies aimed at reducing the negative effects of *P. triestinum* blooms on human health and marine ecosystems **(Pei *et al*., 2022)**. The toxicity potential of this species is not known. The dense blooming of *Prorocentrum triestinum* was significantly reduced in El-Dekhaila Harbor and diatoms, such as *Skeletonema cf. costatum* and *Thalassiosira decipiens* that appeared together with *Prorocentrum triestinum*. In the eastern Mediterranean (Lebanese coastal water), phytoplankton populations primarily included dinoflagellates and diatoms (*Skeletonema* *cf costatum* and *Chaetoceros curvisetus) Leptocylindrus danicus* and *L. minimus,* in addition to some neritic dinoflagellates (*Scrippsiella trochoidea* and *Prorocentrum triestinum*) **(Abboud-Abi Saab, 2009)**. The algal blooms negatively affect the ecosystem's water quality; they secrete various kinds of toxins, putting the affected area at high risk. El Mex Bay, which is located in both the Western and El-Dekhaila harbours, receives a large amount of allochthonous nutrients, which results in severe phytoplankton blooms and worsens eutrophication, a recurring issue in the harbors **(Heneash *et al*., 2022)**. This bay is considered a fishing center for many different species of fish native to Alexandria **(Dorgham *et al*., 2004)**. During the last few years, several harmful algal blooms have created poisons that could accumulate and induce several human syndromes, for example, diarrheal (D.S.P.), amnesic shellfish poisoning (A.S.P.) and paralytic shellfish poisoning (P.S.P.**) (Khan *et al*., 2021)**. Certain species display an association with other species in different groups. For example, *Prorocentrum triestinum* and the *Eutreptiella* sp. appeared together in the Western Harbor in the present study. **Vila *et al*. (2001)** also recorded the same observation in the Kaštel Bay (Adriatic Sea).

Diatoms dominated the newly constructed harbors (Port Said, Damietta, and Sidi Kerir Harbors) in which *Chaetoceros curvisetus, C. affinis, C. didymus, Cerataulina pelagica, Asterionellopsis glacialis, Skeletonema costatum,* and *Pseudo-nitzschia delicatissima* were the dominant species. *Skeletonema costatum* constituted > 50% of the total community in Sidi Kerir Harbor **(Stoemer *et al*., 1999)**; the authors classified *Cerataulina pelagica, Pseudo-nitzschia delicatissima,* and *Skeletonema cf costatum* as potentially toxic or harmful species (domoic acid, A.S.P.). In the studied harbors, the densities of the mentioned species were low and posing no problem, except for *Skeletonema cf costatum*, the common taxon in Sidi Kerir Harbor recorded a density greater than 3×10^5 cells L^{-1}. The main issue is the potential effects of the *Pseudo-nitzschia* species with a maximum density higher than 10^5 cells L^{-1}. The density of this species reached 23×10^3cells L^{-1} in Sidi Kerir Harbor. The distribution of phytoplankton in the two layers of the five harbors showed a clear spatial heterogeneity than in the Western Harbor. Phytoplankton density in the surface layer reached 3.061×10^6 cells L^{-1}, while the subsurface layer sustained only 386×10^3 cells L^{-1}. This observation was elucidated in the study of **Farag (1982)**, who mentioned two currents in the Western Harbor; the first flows from the harbor out to the open sea in the surface layer, and the other flows inside the harbor at a depth of 10m.

Most species detected in the studied harbors are ubiquitous along the Egyptian coast and are therefore known as endemic species. Species diversity indices are good tools for characterizing the five harbors. The Shannon and Wiener phytoplankton diversity index and the Boyed index are good tools for estimating and classifying water quality **(Khan *et al*., 2021)**. High variety was related to high evenness and richness reflecting the multi-dominance form **(Zunino *et al*., 2022)**. Diversity indices of more than

3 indicate clean water; this value was absent in all stations under study. Diversity indices fluctuated between 1 and 3 to distinguish moderately polluted waters, which was the prevailing condition in most stations. Port Said Harbor sustained diversity mostly more than 2. Values less than 1 indicate heavily polluted conditions; this occurred only in the Western Harbor, which was classified as heavily polluted, whereas the other four harbors were catogorized as moderately polluted. Diversity and evenness showed the same trend as most harbors **(Moss *et al*., 1989)**.

Spatial similarity with cluster analysis and principal component analysis (PCA)

The correlation analysis in the studied harbors showed an apparent relationship between the diversity index and species richness. **Zhao *et al.* (2021)** postulated that the species numbers (Richness) were not significant in determining species diversity for the phytoplankton but were closely related to evenness. Actually, they found a robust relationship between evenness and species counts. One important component affecting the phytoplankton diversity has been identified as evenness, or the distribution of abundance between species. The correlations of the present results show that the Shannon index is more suitable than the other indices. The clustering of dissolved oxygen (DO) and salinity is within the same clade, while pH resides in a separate one, suggesting a potential correlation between DO and salinity in influencing the phytoplankton community structure within the marine harbors of the Mediterranean Sea. This clustering pattern indicates that variations in DO and salinity levels might have a synergistic effect on the composition and distribution of phytoplankton species, while the pH levels may exert a distinct influence. Further research exploring the specific mechanisms underlying these relationships could provide valuable insights into the ecological dynamics of these marine ecosystems and aid in effective management and conservation efforts. The analysis of phytoplankton community structure in the marine harbors of the Mediterranean Sea reveals a complex interplay between environmental factors and ecological parameters **(Mensens, 2016)**. In Fig. (3), the species richness and evenness fall under the same component, indicating their interconnectedness within the ecosystem. This finding aligns highlighting the interconnectedness of biodiversity metrics and their implications for environmental health. Ammonia and BOD levels emerge as significant triggers for community analysis, influencing both evenness and richness metrics. The presence of these pollutants can disrupt the balance of species within the phytoplankton community, leading to shifts in both diversity and uniformity. Understanding these dynamics is crucial for effective management and conservation efforts aimed at maintaining the health and stability of marine ecosystems in the Mediterranean harbors. By referencing Fig. (3), which presumably illustrates the placement of these triggers within the evaluation framework, researchers can visually convey the significance of considering both ammonia and BOD in tandem. This visual representation strengthens the argument for their inclusion as interconnected components in studies focused on phytoplankton community dynamics and environmental assessments in the Mediterranean Sea harbors. Further research into the specific mechanisms, by which ammonia and BOD affect phytoplankton communities will be valuable for developing targeted mitigation strategies and promoting sustainable practices in coastal environments. The results of the present study can be summarized as follows: 1) Phytoplankton populations are mainly comprised of diatoms and dinoflagellates; other groups are present in low densities; and the recorded species have been previously recorded in the Egyptian coastal waters and are therefore known as endemic species; 2) Sidi Kerir Harbor was characterized by centric (*Skeletonema cf costatum*) and pennate diatoms (*Asterionellopsis glacialis*), and some neritic dinoflagellates (*Prorocentrum triestinum*); 3) Damiatta Harbor was characterized by the lowest density dominated by the diatoms species as *Asterionellopsis glacialis*, *Chaetoceros curvisetus*, *Cerataulina pelagica* and the dinoflagellates species as *Prorocentrum micans*; 4) The growth of diatoms over dinoflagellates in Port Said Harbor has accelerated and they have become predominant at all stations with most occurrence of *Chaetoceros affinis, Chaetoceros curvisetus* and *Cerataulina pelagica*; 5) The growth of dinoflagellates over diatoms has accelerated, becoming predominant in the Western and El-Dekhaila harbors; 6) The present study favors a continuous monitoring and further assessment (detecting) of phytoplankton (H.A.B.s) which is needed to save these harbors as their economic and ecological importance; 7) The present investigation could provide primary information on phytoplankton abundance and diversity of Sidi Kerir, Port Said and Damietta harbors.

CONCLUSION

Harbors are partially enclosed basins that are immediately impacted by human endeavors, including industrial effluent, urbanization, and shipping. These operations cause pollutants, fertilizers, and other contaminants to enter harbor waters, with a range of negative environmental effects, such as habitat destruction, biodiversity shifts, and eutrophication. An overview of the state of knowledge on the human impacts on marine ecosystems in five important South- eastern Mediterranean Sea harbors is given by the current research. The present results indicate that the waters in the Western and El-Dekhaila harbors are in a bad state, reflecting an unhealthy environment due to the high runoff waters. In addition, these results are compared with the consequences of the last few years of recording obvious variations in the phytoplankton community in addition to future nuisance phytoplankton blooms to set treatment plans. Biodiversity indices were used to identify the level of contamination in the harbors. Continuous monitoring of the hydrological and biological composition of the ecosystem is essential to determine the water quality status of each harbor.

Furthermore, the water quality factors showed a wide variation because of the release of drainage water from various sources of pollution at different times. The present results could provide baseline information on phytoplankton abundance, community structure, and diversity; this information could be a useful tool for further phytoplankton monitoring to predict the overwhelming harmful algal blooms. Coastal administration for the coming projects at harbors needs an environmental control assessment study. This has to be compulsory by law enforcement, monitoring, and upgrading awareness. The findings highlight the need for effective management strategies and pollution control measures to preserve marine ecosystems and safeguard the public health. Overall, the study advances our knowledge of the organization of phytoplankton communities and related environmental variables in the Egyptian harbors, emphasizing the significance of keeping an eye on and evaluating the ecological state of these crucial maritime ecosystems. Future research should focus on long-term monitoring efforts, employing advanced techniques, such as molecular biomarkers and remote sensing, to enhance our understanding of phytoplankton dynamics and environmental responses to human activities. Additionally, collaborative efforts between government agencies, researchers, and local communities are essential for implementing sustainable management practices and promoting environmental conservation in coastal areas.

REFERENCES

Abboud-Abi Saab, M. (2009). Studies and changes of phytoplankton populations in Lebanese coastal waters-a brief overview. Phytoplankt. Responses to Mediterr. Environ. Chang. Tunis., 7-10.

Abdel-Aziz, N. (2006). Vertical migration of zooplankton groups in a eutrophic bay, Dekhaila Harbour, Alexandria, Egypt. Egy. J. of Aqua. Res., 32: 135-157.

Abdel-Aziz, N.E.; Ghobashi, A.E.; Dorgham, M.M. and El-Tohami, W.S. (2007). Qualitative and quantitative study of copepods in damietta Harbour, egypt. Egy. J. of Aqua. Res., 33: 144-162.

Abdel-Halim, A.M. and Aly-Eldeen, M.A. (2016). Characteristics of Mediterranean Sea water in vicinity of Sidikerir Region, west of Alexandria, Egypt. Egy. J. of Aqua. Res., 42:133-140.

Abdel Aziz, N. and Aboul Ezz, S. (2004). The structure of zooplankton community in Lake Maryout, Alexandria, Egypt. Egy. J. of Aqua. Res., 30: 160-170.

Abualnaja, K.M.; Alprol, A.E.; Abu-Saied, M.A.; Ashour, M. and Mansour, A.T. (2021a). Removing of Anionic Dye from Aqueous Solutions by Adsorption Using of Multiwalled Carbon Nanotubes and Poly (Acrylonitrile-styrene) Impregnated with Activated Carbon. Sustainability., 13: 7077.

Abualnaja, K.M.; Alprol, A.E.; Ashour, M. and Mansour, A.T. (2021b). Influencing Multi-Walled Carbon Nanotubes for the Removal of Ismate Violet 2R Dye from Wastewater: Isotherm, Kinetics, and Thermodynamic Studies. Applied Sciences., 11: 4786.

Alprol, A. (2019). Study of environmental concerns of dyes and recent textile effluents treatment technology: a review. Asian J. Fish. Aquat. Res., 3: 1-18.

Alprol, A. E.; Mansour, A. T.; El-Beltagi, H. S. and Ashour, M. J. M. (2023). Algal Extracts for Green Synthesis of Zinc Oxide Nanoparticles: Promising Approach for Algae Bioremediation. Materials., 16 (7): 2819.

Alprol, A.E.; Heneash, A.M.M.; Soliman, A.M.; Ashour, M.; Alsanie, W.F.; Gaber, A. and Mansour, A.T. (2021a). Assessment of Water Quality, Eutrophication, and Zooplankton Community in Lake Burullus, Egypt. Diversity., 13: 268.

Alprol, A.E.; Heneash, A.M.M.; Ashour, M.; Abualnaja, K.M.; Alhashmialameer, D.; Mansour, A.T.; Sharawy, Z.Z.; Abu-Saied, M.A. and Abomohra, A.E. (2021b). Potential Applications of Arthrospira platensis Lipid-Free Biomass in Bioremediation of Organic Dye from Industrial Textile Effluents and Its Influence on Marine Rotifer (*Brachionus plicatilis*). Materials., 14: 1-20.

Alprol, A.E.; Heneash, A.M.M.; Ashour, M.; El-Kafrawy, S. and Soliman, A.M. (2022). Chemical assessment of water quality, heavy metals, and the distribution of zooplankton communities, based on field and .I.S.G.I.S. data in the drains of Burullus Lake, Egypt. Arabian Journal of Geosciences., 15: 511.

APHA. (1998). Standard methods for the examination of water and waste water, 19th edition. APHA, Washington DC, USASS.

Aziz, N.A.; Gharib, S. and Dorgham, M. (2006). The interaction between phytoplankton and zooplankton in a Lake-Sea connection, Alexandria, Egypt. International Journal of Oceans and Oceanography., 1: 151-165.

Buckley, L.B. and Burrows, M.T. (2013). Global imprint of climate change on marine life. Nature Climate Change., 3: 919-925.

Chapman, D. (2021). Water quality assessments: a guide to the use of biota, sediments and water in environmental monitoring. 2nd Edition. R.C.C.R.C. Press. London. https://doi.org/10.1201/9781003062103.

DALE, B. (1983). Dinoflagellate resting cysts:" benthic plankton". In Survival strategies of the algae., 69-136.

Davidson, K.; Gowen, R.J.; Harrison, P.J.; Fleming, L.E.; Hoagland, P. and Moschonas, G. (2014). Anthropogenic nutrients and harmful algae in coastal waters. Journal of environmental management, 146: 206-216.

Dawood, M.; El-Awadi, M.; Sadak, M. and El-Lethy, S. (2019). Comparison between the physiological role of carrot root extract and β-carotene in inducing Helianthus annuus L. drought tolerance. Asian. J. Biol. Sci., 12: 231-241.

DeJong, T. M. (1975). A comparison of three diversity indices based on their components of richness and evenness. Oikos., 222-227.

Dorgham, M.M.; Abdel-Aziz, N.; El-Deeb, K. and Okbah, M. (2004). Eutrophication problems in the western Harbour of Alexandria, Egypt. Oceanologia., 46: 25-44.

Edler, L. and Elbrächter, M. (2010). The Utermöhl method for quantitative phytoplankton analysis. Microscopic and molecular methods for quantitative phytoplankton analysis., 110: 13-20.

El-Amier, Y.A.; El-Alfy, M. and Nofal, M.M. (2018). Macrophytes potential for removal of heavy metals from aquatic ecosystem, Egypt: Using metal accumulation index (M.A.I.). Plant Arch., 18: 2131-2144.

El-Feky, M.M.; Alprol, A.E.; Heneash, A.M.; Abo-Taleb, H.A. and Omer, M.Y. (2019). Evaluation of water quality and plankton for Mahmoudia Canal in Northern West of Egypt. Egy. J. of Aqua. Res., 22: 461-474.

El-Ghobashi, A., Abdel-Aziz, N.E., Dorgham, M.M., El-Tohamy, W.S. (2006). Effect of the maritime activities and Nile discharge on ecological and biological characteristics of Damietta Harbour, Egypt. Bull. Nat. Inst. Oceanogr. Fish., 32: 16-33.

El-Sadaawy, M.; El-Said, G.F.; Khalil, M.; Morsy, F.A. and Draz, S.E. (2022). A Comparison of Pollution, Environmental Hazards, Sedimentology, and Geochemistry, In Five Economic Harbours Along the Egyptian Coast of Mediterranean Sea. Europe B.M.C., Preprint. https://doi.org/10.21203/rs.3.rs-1097962/v1.

El-Sherbiny, M.; Aamer, M. and Gab-Alla, A. (2006). Effect of dredging and dumping operations on zooplankton community during the construction of East Branch Harbour, Port Said, Eastern Mediterranean, Egypt. Catrina: The International Journal of Environmental Sciences., 1: 53-62.

El-Zeiny, A. and El-Kafrawy, S. (2017). Assessment of water pollution induced by human activities in Burullus Lake using Landsat 8 operational land imager and G.I.S. The Egyptian Journal of Remote Sensing and Space Science., 20: S49-S56.

El Zokm, G.M.; Tadros, H.R.; Okbah, M.A. and Ibrahim, G.H. (2018). Eutrophication assessment using TRIX and Carlson’s indices in Lake Mariout Water, Egypt. Egy. J. of Aqua. Bio & Fish., 22: 331-349.

Farag, M. (1982). Circulation pattern and hydrographic structure of EL-Mex and Western Harbour Area. M. Sci. Thesis, Fac. Sci., Alex. Univ.

Faragallah, H.; Askar, A.; Okbah, M. and Moustafa, H. (2009). Physico-chemical characteristics of the open Mediterranean sea water for about 60 Km from Damietta Harbour, Egypt. Journal of Ecology and The Natural Environment., 1: 106-119.

Federation, W. and Association, A. (2005). Standard methods for the examination of water and wastewater, Am. Public Health Assoc. APHA Wash. DC USA.

Gab-Allah, M.M. and Touliabah, H.E. (2014). Pollution study in El-Gameel coast, Port Said, Egypt and its impact on phytoplankton community. Egyptian Journal of Experimental Biology (Bot.)., 10: 87-96.

Gharib, S. and Dorgham, M. (2006). Eutrophication stress on phytoplankton community in the Western Harbour of Alexandria, Egypt. Int. J. Ocean Oceanogr., 1: 261-273.

Giacobbe, M.; Oliva, F. and Maimone, G. (1996). Environmental Factors and Seasonal Occurrence of the DinoflagellateAlexandrium minutum, a PSP Potential Producer, in a Mediterranean Lagoon. Estuarine, Coastal and Shelf Science, 42: 539-549.

Fatourou, E.; Kafetzidou, A.; Marret, F.; Panagiotopoulos, K. and Kouli, K. J. M. M. (2023). Late Quaternary Ponto-Caspian dinoflagellate cyst assemblages from the Gulf of Corinth, Central Greece (eastern Mediterranean Sea). Marine Micropaleontology., 179: 102211.

Fischer, A. D.; Brosnahan, M. L. and Anderson, D. M. J. P. (2018). Quantitative response of Alexandrium catenella cyst dormancy to cold exposure. Protist., 169(5): 645-661.

Heneash, A. M.; Alprol, A. E.; El-Naggar, H. A.; Gharib, S. M.; Hosny, S.; El-Alfy, M. A. and El-Hamid, H. T. (2022). Multivariate analysis of plankton variability and water pollution in two highly dynamic sites, southeastern Mediterranean (Egyptian coast). Arabian Journal of Geosciences., 15(4): 330.

Halim, Y. (1960). *Alexandrium minutumnov*. sp. dinoflagellé provocant des «eaux rouges». Vie et milieu., 11: 102-105.

Heneash, A. and Alprol, A. (2020). Monitoring of water quality and zooplankton community in presence of different dietary levels of commercial wood charcoal of red tilapia. J. Aquac. Res. Dev., 11: 1-6.

Heneash, A.M. (2015). www. ijarbs. com Coden: IJARQG (USA). Int. J. Adv. Res. Biol. Sci., 2: 39-51.

Heneash, A.M.; Abdel-Rahman, N.S. and Gharib, S.M. (2015a). Community composition, abundance and biomass of tintinnids (Ciliata: Protozoa) in the

Western Harbour, southeastern Mediterranean Sea, Egypt. Environmental monitoring and assessment., 187: 1-14.

Heneash, A.M.; Alprol, A.E.; El-Hamid, A.; Hazem, T.; Khater, M. and El Damhogy, K.A. (2021). Assessment of water pollution induced by anthropogenic activities on zooplankton community in Mariout Lake using statistical simulation. Arabian Journal of Geosciences., 14: 1-21.

Heneash, A. M.; Alprol, A. E. and Abdelkhalek, D. (2022). Short-Term Scale Observations on Zooplankton Community and Water Quality in the Eastern Harbor of Alexandria, Egypt. gyptian Journal of Aquatic Biology and Fisheries., 26(2): 197-216.

Heneash, A.M.; Tadrose, H.R.; Hussein, M.M.; Hamdona, S.K.; Abdel-Aziz, N. and Gharib, S.M. (2015b). Potential effects of abiotic factors on the abundance and distribution of the plankton in the Western Harbour, southeastern Mediterranean Sea, Egypt. Oceanologia., 57: 61-70.

Ismael, A.A. and Dorgham, M. M. (2003). Ecological indices as a tool for assessing pollution in El-Dekhaila Harbour (Alexandria, Egypt). Oceanologia., 45: 121-131.

Khairy, H.M. and Gharib, S.M. (2017). Research Article Factors Regulating Composition and Abundance of Phytoplankton in El Dekhaila Harbour, Southeastern Mediterranean Sea, Egypt. Asian Journal of Biological Sciences., 10: 27-37.

Khedr, A.I.; Soliman, Y.A.; El-Sherbeny, E.F.; Hamed, M.A.; Ahmed, M.A. and Goher, M.E. (2019). Water Quality Assessment of the northern part of Suez Gulf (Red Sea, Egypt), using Principal Component Analysis. Egy. J. of Aqua. Res., 23: 527-538.

Koray, T. (2002). Potentially toxic and harmful phytoplankton species along the coast of the Turkish Seas. Harmful Algae., 335-337.

Khan, R. M.; Salehi, B.; Mahdianpari, M.; Mohammadimanesh, F.; Mountrakis, G. and Quackenbush, L. J. J. R. S. (2021). A meta-analysis on harmful algal bloom (HAB) detection and monitoring: a remote sensing perspective., 13(21): 4347.

Labib, W. and Halim, Y. (1995). Diel vertical migration and toxicity of Alexandrium minutum Halim red tide, in Alexandria, Egypt. Marine life (Marseille)., 5: 11-17.

Mensens, C. (2016). Biodiversity and ecosystem functioning in stressed environments: primary producers and consumers at the basis of marine food webs. Ghent University, Belgium.

Metwally, A.S.; El-Naggar, H.A.; El-Damhougy, K.A.; Bashar, M.A.E.; Ashour, M. and Abo-Taleb, H.A.H. (2020). GC-MS analysis of bioactive components in six different crude extracts from the Soft Coral (*Sinularia maxim*) collected from Ras Mohamed, Aqaba Gulf, Red Sea, Egypt. Egy. J. of Aqua. Res., 24: 425 –434.

Moss, B.; Booker, I.; Balls, H. and Manson, K. (1989). Phytoplankton distribution in a temperate floodplain lake and river system. Hydrology, nutrient sources and phytoplankton biomass. Journal of plankton research., 11: 813-838.

Nguyen, T.N.P.; Bui, Q.T.P. and Huang, C. (2018). Performance evaluation of a hydrogen-fed bioreactor treating nitrate containing wastewater under long-term operation. Sustainable Environment Research., 28: 274-281.

Ndhlovu, A.; Dhar, N.; Garg, N.; Xuma, T.; Pitcher, G. C.; Sym, S. D. and Durand, P. M. J. P. (2017). A red tide forming dinoflagellate *Prorocentrum triestinum*: identification, phylogeny and impacts on St Helena Bay, South Africa. Phycologia., 56(6): 649-665.

Pei, L.; Hu, W.; Wang, P.; Kang, J.; Mohamed, H. F.; Wang, C. and Luo, Z. J. A. R. (2022). Morphologic and phylogenic characterization of two bloom-forming planktonic Prorocentrum (Dinophyceae) species and their potential distribution in the China Sea. Algal Research., 66: 102788.

Poloczanska, E.S.; Brown, C.J.; Sydeman, W.J.; Kiessling, W.; Schoeman, D.S.; Moore, P.J.; Brander, K.; Bruno, J.F.; Buckley, L.B. and Burrows, M.T. (2013). Global imprint of climate change on marine life. Nature Climate Change., 3: 919-925.

Reed, C. (1978.) Species diversity in aquatic microecosystems. Ecology., 59: 481-488.

Shaltout, N. and Abd-El-Khalek, D. (2014). Assessment of Seawater Quality of El-Dekhaila Harbour, Alexandria, Egypt. Asian J. of Adv. Basic Sci., 3:206-216.

Shannon, C. E. and Wiener, W. (1963). The mathematical theory of communities. University of Illinois press, Urbana 117.

Soliman, Z. I. (2006). A study of heavy metals pollution in some aquatic organisms in Suez Canal in Port-Said Harbour. Journal of Applied Sciences Research., 2: 657-663.

Stoemer, E.; Fryxell, G.; Smol, J. and Villac, M. (1999). Toxic and harmful marine diatoms. The diatoms: applications for the environmental and earth sciences., 419-428.

Tarazona-Janampa, U. I.; Cembella, A. D.; Pelayo-Zárate, M. C.; Pajares, S.; Márquez-Valdelamar, L. M.; Okolodkov, Y. B. and Durán-Riveroll, L. M. J. F. i. M. S. (2020). Associated bacteria and their effects on growth and toxigenicity of the dinoflagellate Prorocentrum lima species complex from epibenthic substrates along mexican coasts. Frontiers in Marine Science., 7: 569.

Tsikoti, C. and Genitsaris, S. J. D. (2021). Review of harmful algal blooms in the coastal Mediterranean Sea, with a focus on Greek waters. Diversity., 13(8): 396.

Vila, M.; Camp, J.; Garcés, E.; Masó, M. and Delgado, M. (2001). High resolution spatio-temporal detection of potentially harmful dinoflagellates in confined waters of the.W.N.W. Mediterranean. Journal of plankton research., 23: 497-514.

Vila, M. and Masó, M. (2005).Phytoplankton functional groups and harmful algae species in anthropogenically impacted waters of the NW Mediterranean Sea. Scientia Marina., 69: 31-45.

Wolda, H. (1983). Diversity indices and tropical cockroaches. Oecologia., 58: 290-298.

Wu, R. (1982). Effects of taxonomic uncertainty on species diversity indices. Marine Environmental, Research., 6: 215-225.

Zhao, K.; Wang, L.; You, Q.; Pan, Y.; Liu, T.; Zhou, Y. and Wang, Q. J. S. (2021). Influence of cyanobacterial blooms and environmental variation on zooplankton and eukaryotic phytoplankton in a large, shallow, eutrophic lake in China. Science of The Total Environment, 773: 145421.

Zunino, J.; La Colla, N. S.; Brendel, A. S.; Alfonso, M. B.; Botté, S. E. and Perillo, G. M. (2022). Water quality analysis based on phytoplankton and metal indices: a case study in the Sauce Grande River Basin (Argentina). Environmental Science and Pollution Research., 29 (52): 79053-79066.

Zaghloul, F.A.; Abdalla, R.; Moustafa, H. and Badr, A. (1995).Phytoplankton community structure in El-dekhaila harbour ofalexandria, Egypt. Bull. Nat. Inst. Oceanogr. Fish., 21:103-123.

Zakaria, H.Y.; Radwan, A. and Said, M. (2007). Influence of salinity variations on zooplankton community in El-Mex Bay, Alexandria, Egypt. Egy. J. of Aqua. Res., 33: 52-67.

Zaki, M.A.; Ashour, M.; Heneash, A.M.M.; Mabrouk, M.M.; Alprol, A.E.; Khairy, H.M.; Nour, A.M.; Mansour, A.T.; Hassanien, H.A.; Gber, A. and Elshobary, M.E. (2021). Potential Applications of Native Cyanobacterium Isolate (*Arthrospira platensis* NIOF17/003) for Biodiesel Production and Utilization of Its Byproduct in Marine Rotifer (Brachionus plicatilis) Production. Sustainability., 13: 1769.

Zein, M. and Gharb, S. M. (2014). Spatial and temporal patterns of phytoplankton composition in Burullus Lagoon, Southern Mediterranean Coast, Egypt. The Egy. J. of Aqua. Res., 40: 133-142. https://doi.org/10.1016/j.ejar.2014.06.004.